**NEXRAD Severe Weather Signatures in the NOAA Severe Weather Data Inventory**

Steve Ansari *, Mark Phillips, Stephen Del Greco

NOAA National Climatic Data Center, Asheville, North Carolina

## ABSTRACT

The Severe Weather Data Inventory (SWDI) at NOAA's National Climatic Data Center (NCDC) provides user access to archives of several datasets critical to the detection and evaluation of severe weather. These datasets include

- NEXRAD Level-III point features describing general storm structure, hail, mesocyclone and tornado signatures from 1995 to present. Current number of features in SWDI (January 1995 - April 2009, with product codes in parentheses):
  - Storm Structure (NSS): 254,923,000
  - Mesocyclone (NME): 19,136,000
  - Digital Mesocyclone (NMD): 2,134,000
  - Hail (NHI): 93,136,880
  - Tornado Vortex Signature (NTV): 348,000
- NOAA's National Weather Service Storm Events Database
- NOAA's National Weather Service Preliminary Local Storm Reports collected from storm spotters
- NOAA's National Weather Service Watches and Warnings
- Lightning strikes from Vaisala's National Lightning Detection Network (NLDN) (.gov and .mil only)

SWDI stores these datasets in a spatial database that allows for convenient searching and subsetting. These data are accessible via the NCDC web site, FTP or automated web services. The results of interactive web page queries may be saved in a variety of formats, including plain text, XML, Google Earth's KMZ and Shapefile. In the future, the SWDI platform may be utilized for algorithm output from reanalysis and data mining projects in addition to simple quality control flags based on queries such as "Select all tornado signatures within a severe thunderstorm warning (spatially and temporally)".

## 1. INTRODUCTION

Severe weather impacts the lives of millions of people each year. The protection, planning, and response to these challenges are central to NOAA's mitigation, and recovery which is often atop public perception and occupies many of NOAA's resources. Tools to aid in this mission are important for many reasons. Better preparedness and improved recovery can help save lives, reduce costs, and provide comfort. The development of NEXRAD Radar systems have dramatically improved severe weather detection and have saved countless lives. Algorithms developed at the National Weather Service (NWS) use NEXRAD data to detect and track tornados, hail and mesocyclones in real-time. While these data are invaluable for real-time operations, historical analysis is also beneficial. Comparison with other independent data sources such as human observations and lightning sensors provides a long-term source of quality assurance. The observational data tends to show biased information because reports are often located in populated places or along major roads. The remotely sensed data allows for a more homogenously spaced distribution of weather information.

## 2. DATA

Five initial data sources for the SWDI are the NEXRAD Level-III NWS-derived products, the National Weather Service (NWS) Storm Events Database, the NWS Local Storm Reports, the NWS Warning areas and the National Lightning Detection Network (NLDN). The NEXRAD Level-III data are products generated with NWS algorithms from NEXRAD Level-II (base) volume scan data. Several of the Level-III products identify and describe severe weather. These products consist of mesocyclone, hail, tornado and storm structure point features which are decoded and geo-located using the Weather and Climate Toolkit software package [1] (Figure 1).

The temporal resolution of the NEXRAD derived datasets is dependant on the scan mode of the Radar site and varies between 4 and 10 minutes. The entire NCDC archive of NEXRAD data has been reprocessed to populate the SWDI. This includes general coverage of the continental United States since 1995 with the earliest data from 1991. There are currently over 370 Million NEXRAD records in SWDI (1991 – April 2009). The data is updated daily.

The Local Storm Reports are preliminary reports from trained sources such as storm spotters, law enforcement, emergency response, etc… These reports are later verified by the NWS and added to the Storm Events Database.

The Storm Events Database consists of verified qualitative observations of events such as hail, tornados, lightning, flooding, high wind and more. The data either have a geographic coordinate specified or are organized by county or city. The Storm Events data are event

* *Corresponding author address:* Steve Ansari, 151 Patton Avenue, Asheville, NC 28801; e-mail: Steve.Ansari@noaa.gov.

summaries and contain data from 1950 to the present [8] (Figure 3).

The NWS Warnings include the current polygon and legacy county-based warnings for severe thunderstorms, tornados and flash flooding.

The NLDN (NOAAPORT stream) data are generated from Vaisala's national network of lightning sensors. The sensors use time-of-arrival and magnetic direction finding to identify and geo-locate each lightning event [2] (Figure 2). The temporal resolution of NLDN data is one second. The raw NLDN data is only available to .gov and .mil users. Derived products, such as daily count per county, are available to all users.

Future datasets include polygon areas of interest derived from gridded datasets such as NEXRAD and/or Multi-Sensor precipitation estimates, hail estimates

## 3. GEOSPATIAL DATABASE

A geospatial database is used to manage the data in the SWDI. The database spatially links the diverse datasets together in a way that is not possible using conventional databases or data storage methods [6]. Having the severe weather data in a central geospatial database links the data to each other in addition to other NCDC datasets. For example, the state, county, climate division and interstates are precalculated for all SWDI datasets. Additional spatial relationships between the SWDI datasets are also precalculated, allowing fast queries such as “Select all NEXRAD TVS or Hail signatures that are within a Severe Thunderstorm or Tornado Warning (spatially and temporally)”. The simple, modular design allows datasets to remain unique and independent while sharing only a spatial relationship (Figure 4). A geographic location is all that is needed to add new datasets to the SWDI. This offers a high level of flexibility in dealing with many different types of data from various sources.

## 4. ACCESS

Several access methods are provided to accommodate various types of users. Web pages provide numerous interactive search options. Data may be downloaded in common formats such as plain text (CSV), XML, KMZ and Shapefile [Appendix A]. Users are able to search on several criteria including location, city, county, state, climate division, hydrologic unit, time period and product. Summary statistics, such as daily counts, allow efficient discovery of days with severe weather activity (Figures 5, 6).

Web services provide automated access to the data via several established protocols. Custom RESTful web services allow the download of data in common formats such as plain text (CSV), XML, KMZ and Shapefile [2]. Each query has a unique URL that exactly describes the data request. This URL is all that is needed to download the data, and can be reused to get the same data at a later date.

The REST services use a folder syntax to represent the virtual data structure. The purpose of this syntax to is to separate the parent-child relationships from the searching or filtering operations. For example, the URL: ‘http://www.ncdc.noaa.gov/swdiws/csv/nx3tvs/20070501:20070601’, represents a query of one month of NEXRAD TVS data in text CSV format. Query parameters are used for filtering. Example query parameters include: ‘?stat=count’, ?stat=tilesum:-85.4,34.5’, ‘?radius=5.0&center=-90.0,46.0’, ‘?state=LA’, ‘?huc=10042357’. For more examples, refer to Appendix B.

## 5. CLIMATOLOGY PRODUCTS

Simple climatology products are under development for the datasets in SWDI. These climatologies have promising applications for the Storm Risk Assessment Project, as well as providing indications of algorithm performance. A climatological look at 7 years of NEXRAD Level-III Hail Signatures reveals possible problem areas for the algorithm (Figure 7). The climotology was created by treating any hail signature within a single grid cell and 10 minute period as a single signature, thus eliminating bias from overlapping Radars. As NEXRAD algorithms improve, the capability at NCDC for reprocessing raw Level-II to produce improved datasets is a unique capability with many benefits to multiple user communities.

## 6. STORM RISK ASSESSMENT PROJECT

The Storm Risk Assessment Project builds upon the access and query capabilities in the SWDI to produce climatology products. The climatology products are merged with socio-economic datasets to quantify and assess risks of severe weather to lives and property. The assessments are invaluable to a diverse set of users such as emergency management, municipal planning, the insurance industry and many others.

## 7. CONCLUSION

The SWDI provides efficient and user-friendly access to an extensive archive of severe weather data. The SWDI will aid in the quality control of severe weather products, facilitate new research and assist disaster response and mitigation. The relational geospatial database provides a modular, flexible solution for data storage and management. This allows SWDI datasets such as NEXRAD, NLDN, Weather Warnings and observational Storm Events to remain independent while sharing a common spatial relationship. Multiple data access methods are provided to satisfy different types of users. Interactive web pages provide extensive search options while web services offer an efficient method of automated data access. By incorporating web services, users may seamlessly integrate the SWDI into custom applications. The SWDI presents valuable severe weather data in a simple, flexible manner that benefits many user communities and exemplifies the overall NOAA mission.

## 8. REFERENCES

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2. "Building Web Services the REST Way", Website: http://www.xfront.com/REST-Web-Services.html

3. Cummins, K. L., M. J. Murphy, E. A. Bardo, W. L. Hiscox, R. B. Pyle, and A. E. Pifer, 1998. A Combined TOA/MDF Technology Upgrade of the U. S. National Lightning Detection Network, J. Geophys. Res., 103, 9035-9044. Idone, V. P.,

4. Oracle Spatial Website: http://www.oracle.com/technology/products/spatial/index.html

5. SOAP Reference Website: http://www.xml.org/xml/resources_focus_soap.shtml

6. Storm Events Website: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms

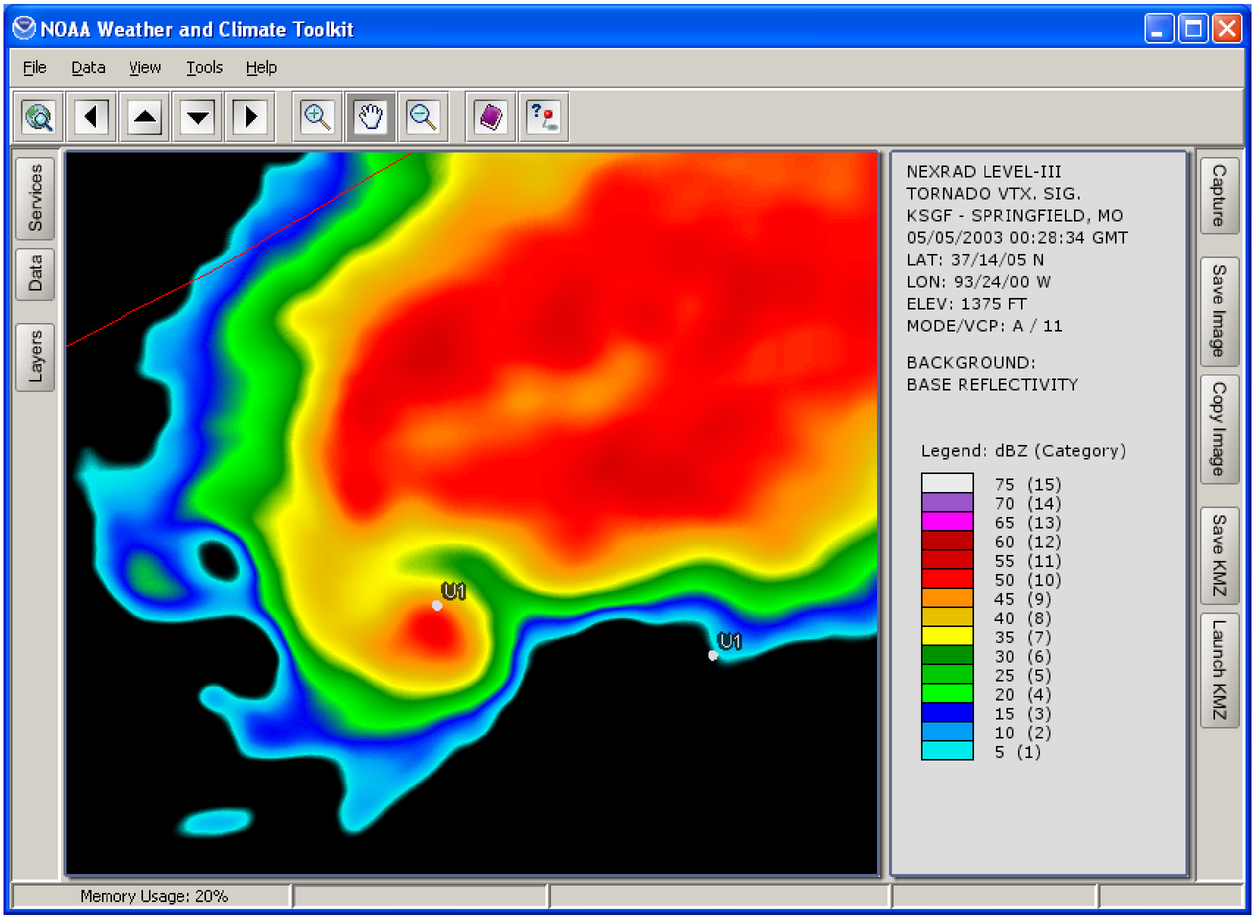


***Figure 1. NEXRAD Level-III Tornado Vortex Signature and Reflectivity Data***

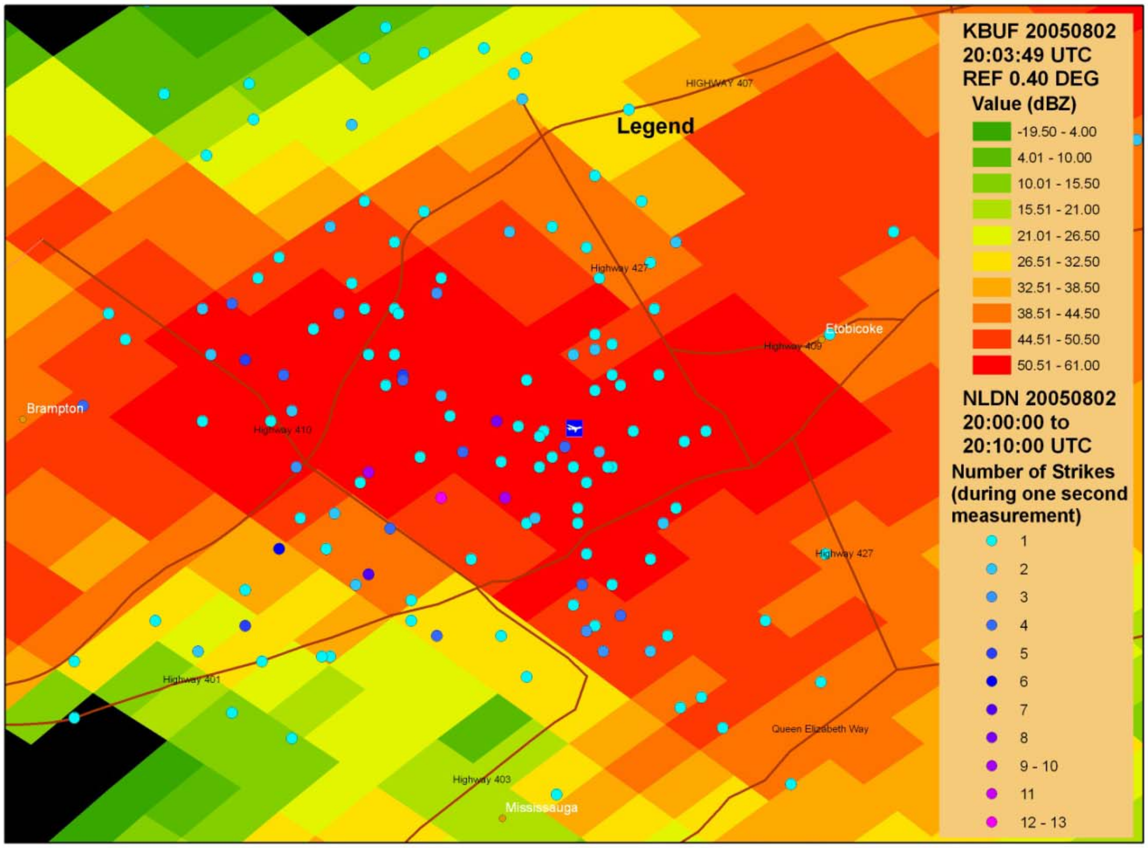


*Figure 2. NLDN and NEXRAD Reflectivity Data*

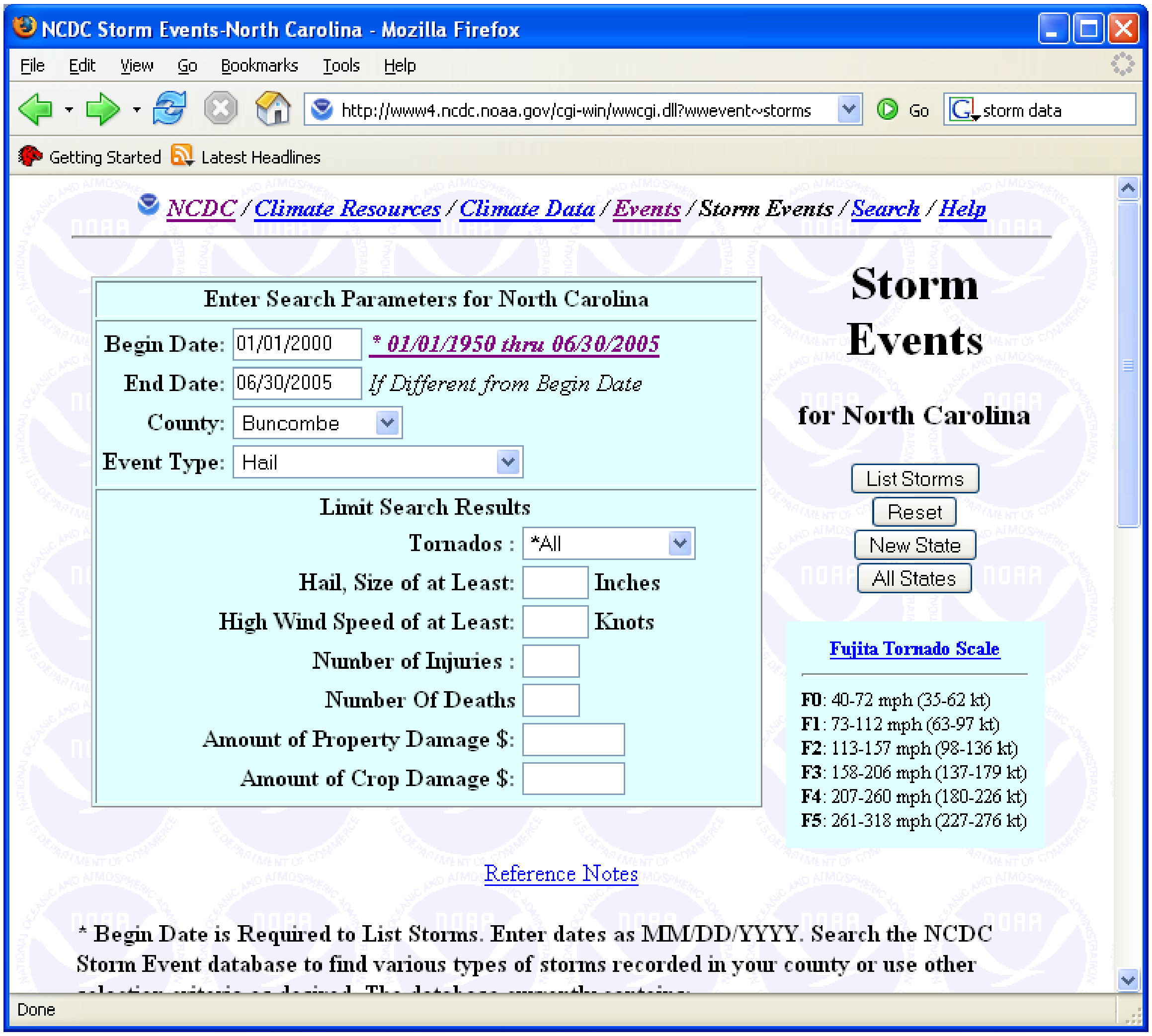


***Figure 3. Storm Events Database***

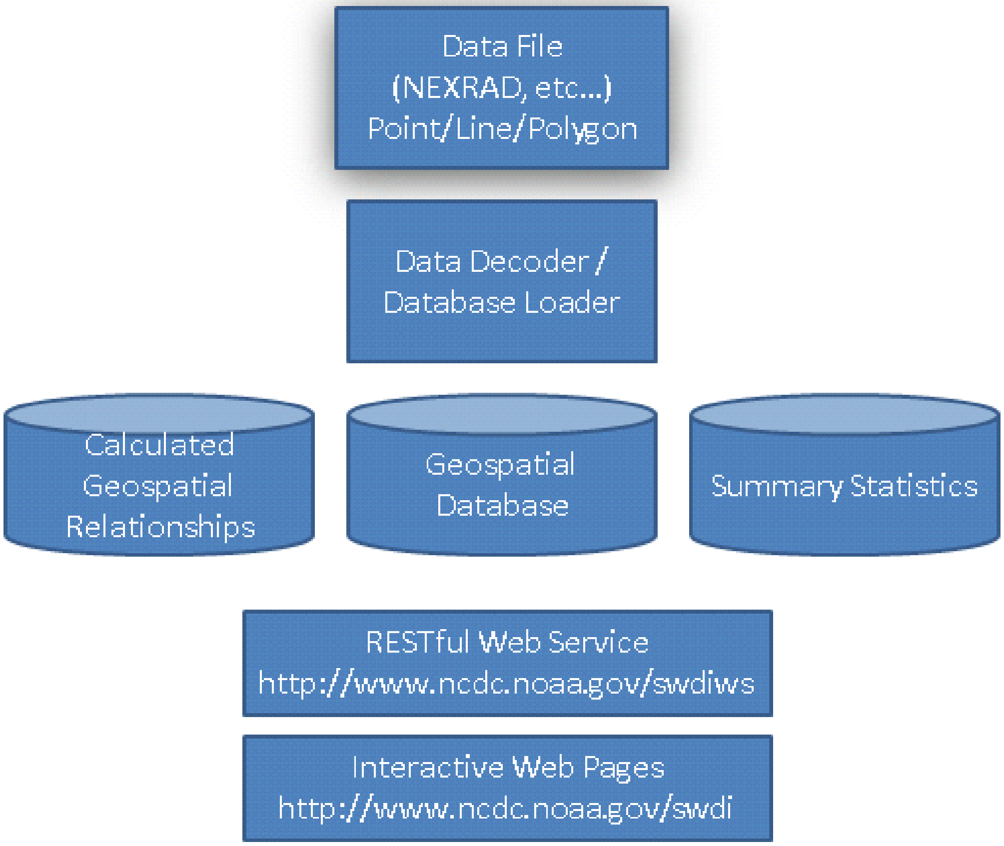


***Figure 4. Severe Weather Data Inventory Flowchart***

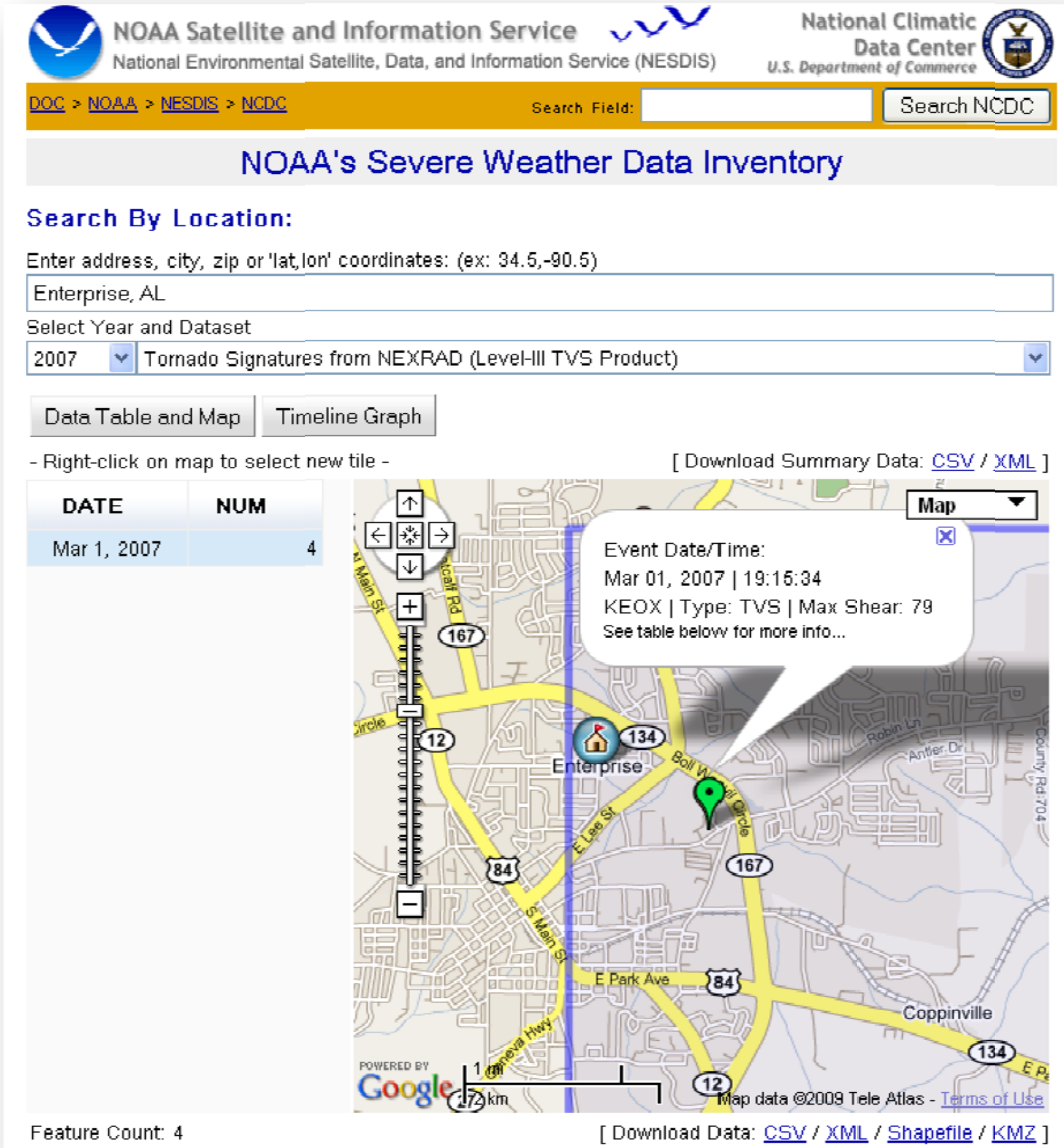


***Figure 5. Severe Weather Data Inventory Interactive Web Page Access***

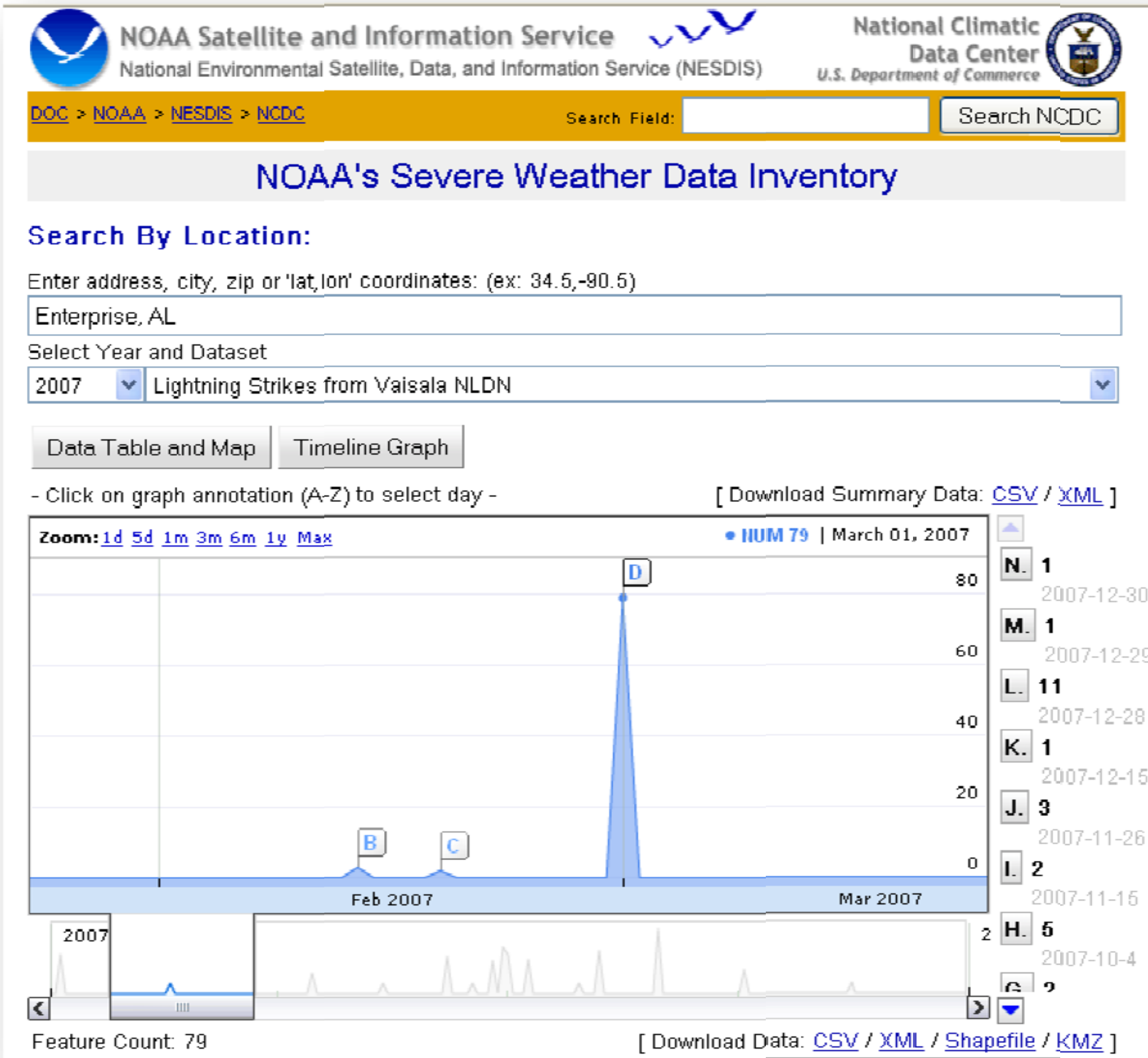


***Figure 6. Severe Weather Data Inventory Interactive Web Page Search Results***

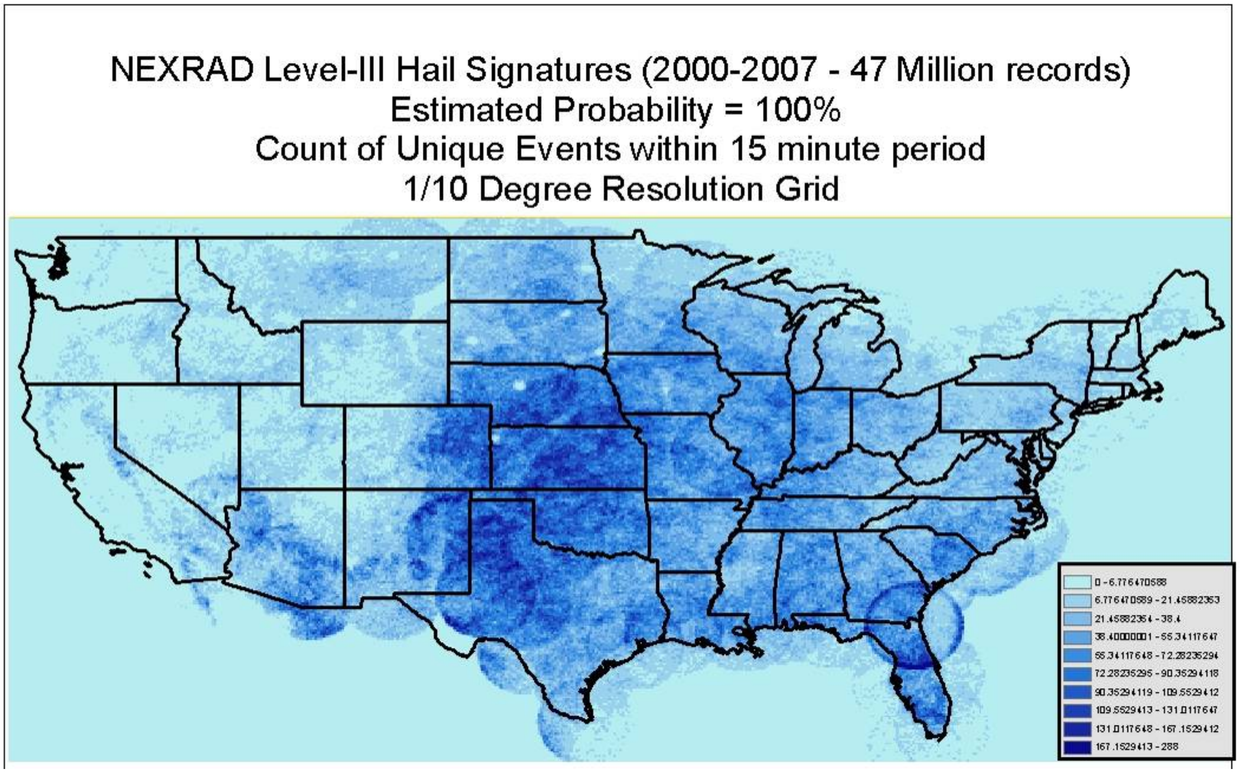


***Figure 7. Climatology of NEXRAD Level-III Hail Signature occurrences (2000-2007)***

**APPENDIX A**

1. ESRI Shapefile [1]: “A shapefile stores nontopological geometry and attribute information for the spatial features in a data set. The geometry for a feature is stored as a shape comprising a set of vector coordinates.” For more information: http://www.esri.com

2. Geography Markup Language (GML): “Geography Markup Language is an XML grammar written in XML Schema for the modeling, transport, and storage of geographic information.” For more information: http://www.opengis.net/gml/

3. Well-Known Text (WKT): An ASCII text representation of geometry data. Defined in the OpenGIS Consortium “Simple Features for SQL” specification. For more information: http://dev.mysql.com/doc/mysql/en/GIS_WKT_format.html or http://publib.boulder.ibm.com/infocenter/db2help/index.jsp?topic=/com.ibm.db2.udb.doc/opt/rsbp4120.htm

4. NetCDF (network Common Data Form): “NetCDF (network Common Data Form) is an interface for array-oriented data access and a freely-distributed collection of software libraries for C, Fortran, C++, Java, and perl that provide implementations of the interface. The netCDF software was developed by Glenn Davis, Russ Rew, Steve Emmerson, John Caron, and Harvey Davies at the Unidata Program Center in Boulder, Colorado, and augmented by contributions from other netCDF users. The netCDF libraries define a machine-independent format for representing scientific data. Together, the interface, libraries, and format support the creation, access, and sharing of scientific data.” For more information: http://my.unidata.ucar.edu/content/software/netcdf/index.html

**APPENDIX B**

SWDI REST Web Service URL Examples:

1) Query for one day of NEXRAD TVS data in a zipped Shapefile:

http://www.ncdc.noaa.gov/swdiws/shp/nx3tvs/20070301

2) Query for the first 25 records of NEXRAD TVS data in CSV format from March 1st, 2007:

http://www.ncdc.noaa.gov/swdiws/csv/nx3tvs/20070301/25

3) Query for the second set of 25 records from Query #2:

http://www.ncdc.noaa.gov/swdiws/csv/nx3tvs/20070301/25/26

4) Calculate only the number of results:

http://www.ncdc.noaa.gov/swdiws/csv/nx3tvs/20070301?stat=count

5) Filter the results to the 0.1Deg tile containing the location -96.0, 35.0:

http://www.ncdc.noaa.gov/swdiws/nx3tvs/20070301?tile=-96.0,35.0

6) Filter the results to 10 miles of the location -96.0, 35.0:

http://www.ncdc.noaa.gov/swdiws/csv/nx3tvs/20070301?center=-96.0,35.0&radius=10.0

7) Filter the results to the state of Kansas:

http://www.ncdc.noaa.gov/swdiws/csv/nx3tvs/20070301:20070401?state=KS